



## ASSESSMENT OF ARSENIC IN GROUNDWATER IN MONGUNO, BORNO STATE, NIGERIA

I. M. Umar<sup>1\*</sup>, B. M. Sheriff<sup>2</sup> and B. B. Muhammad<sup>3</sup>

<sup>1</sup>School of Architecture, Building and Civil Engineering, Loughborough University, London, UK.

<sup>2</sup>Department of Geology, University of Maiduguri, Maiduguri, Borno State, Nigeria.

<sup>3</sup>Department of Civil & Water Resources Engineering, University of Maiduguri, Maiduguri, Borno State

\*Corresponding author's email address: [enr.ibraheem1@gmail.com](mailto:enr.ibraheem1@gmail.com)

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### ABSTRACT

Arsenic contamination poses a severe health threat in the semi-arid region of North-eastern Nigeria, particularly in Monguno town, Borno State. This study rigorously evaluated groundwater arsenic concentrations in 102 samples from various boreholes across Upper, Middle, and Lower aquifers of the Chad Formation, utilizing the Palintest Digital Arsenator Test Kit. To ensure precision, each water sample underwent analysis twice, totaling 204 tested and analyzed samples. Furthermore, the geographical coordinates of the 102 boreholes were meticulously mapped using QGIS (Quantum Geographic Information System), providing a visual representation and analysis of the arsenic presence. Findings revealed that only 3 samples met the WHO recommended threshold, 56 fell within the 10-50 µg/L range, signifying a low risk, while 43 samples exceeded 50 µg/L, breaching safety limits. Prolonged exposure to high arsenic levels can lead to severe health implications. A comprehensive human health risk assessment considered parameters such as Average Daily Dose (ADD), Hazard Quotient (HQ), and Cancer Risk (CR). Notably, for 43 water sources with arsenic concentrations exceeding 50 µg/L, Hazard Quotient (HQ) values ranged from 1.2 to 5.3, indicating potential health risks. These elevated values underscore potential carcinogenic and non-carcinogenic hazards in Monguno. A direct linear relationship was observed between HQ and arsenic concentrations across all samples, reinforcing the correlation. Despite the absence of specific reference values for Monguno, the analogous trend in North Central Nigeria reinforces this observation. Urgent collaborative efforts are imperative for intervention and remediation, emphasizing the need for cooperation between government agencies, non-governmental organizations, research institutions, and the local community. Continuous research and monitoring are vital to understanding arsenic sources and distribution, ensuring the long-term effectiveness of remediation measures, and securing safe drinking water access for the community.

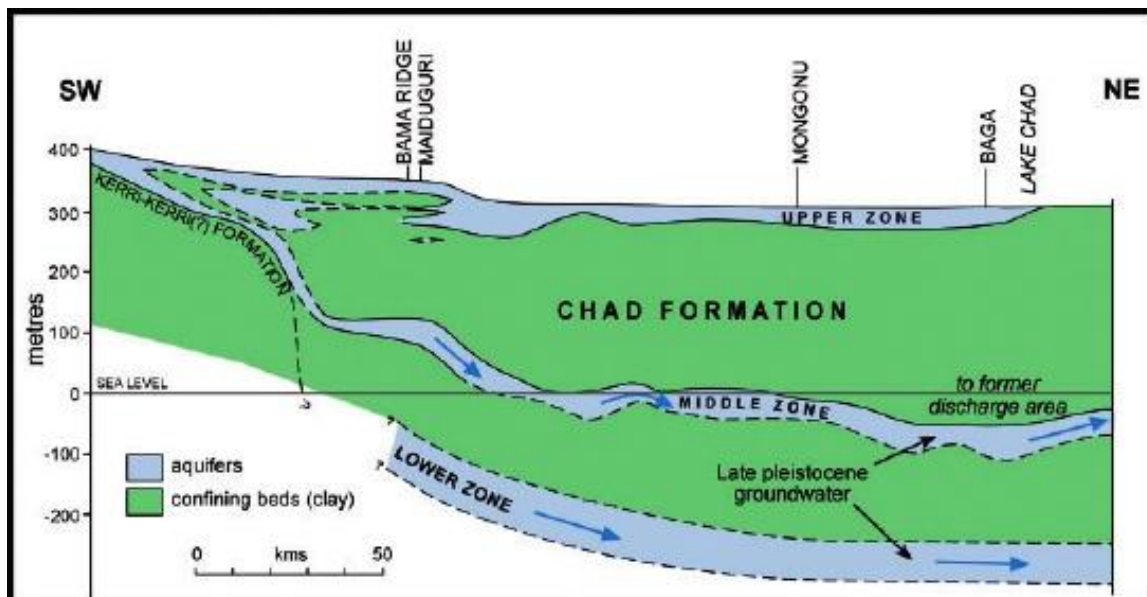
### 1.0 Introduction

Water is a vital prerequisite for the sustenance of life, yet its consumption is subject to both quantitative and qualitative constraints. Consequently, inhabitants of a specific locality may encounter water scarcity and health-related hazards stemming from the ingestion of contaminated water. Globally, the uneven distribution of freshwater resources and population densities has created significant challenges in ensuring access to safe water for millions of people. Throughout history, individuals residing in arid and semiarid regions have strived to secure access to water that is conducive to maintaining a healthy lifestyle. The issue of

insufficient clean water is further exacerbated by the contamination of freshwater sources with various toxic pollutants (Qu et al., 2019).

Aquifers are acknowledged as essential assets that underpin the predominant provision of potable water and essential socio-economic and ecological activities across Africa (Gaye and Tindimugaya, 2019). The utilization of groundwater is integral to the foundational aspects of planning for climate-resilient water supply, particularly in areas susceptible to drought (Howard et al., 2016; Pavelic et al., 2012).

In the context of Nigeria, groundwater constitutes the primary potable water supply for more than 75% of the populace. Specifically, in Monguno, the use of groundwater is at the peak demand and the main aquifer employed for water extraction is predominantly associated with the geological formation of the Lake Chad basin. According to Barber and Jones (1960), the Chad Formation can be divided into three aquiferous zones: Upper, Middle, and Lower aquifers. The Upper aquifer is mostly unconfined and semi-confined, while the Middle and Lower aquifers are confined. The Middle aquifer is primarily composed of fine to medium-grained sand, interbedded with silty and clayey layers, at a depth of approximately 250 meters with an average thickness of about 50 meters. The Lower aquifer, found in areas such as Maiduguri, Gudumbali, Kukawa, and Monguno, varies in depth from 250 meters to 500 meters, depending on the local geology, as depicted in Figure 1.



**Figure 1:** Cross-section of the Chad Formation (after Barber and Jones, 1960)

Arsenic contamination of groundwater represents a significant global health challenge, as evidenced by numerous studies (Neil et al., 2018; Wei et al., 2018; Shakoor et al., 2019). The severity of this issue is underscored by the exposure of over 200 million individuals worldwide to arsenic-contaminated groundwater exceeding 10 µg/L, primarily through the consumption of drinking water (Naujokas et al., 2013; Shahid et al., 2018; Shakoor et al., 2018; Singh et al., 2018). Consequently, the contamination of groundwater with arsenic poses significant health risks, leading to arsenic poisoning on a global scale for millions of people (Bhowmick et al., 2018; Cao et al., 2018; Gonzalez-Martinez et al., 2018).

Contamination of groundwater with arsenic (As) can arise from both natural and anthropogenic sources. Natural occurrences may result from the dissolution of minerals containing arsenic at deeper levels of groundwater, as documented in various studies (Nath et al., 2018; Neil et al., 2018; Saunders et al., 2018). Arsenic (As) is a naturally occurring trace element found in various rocks and sediments. Its release into groundwater depends on factors such as the chemical form of arsenic, the geochemical conditions in the aquifer, and

biogeochemical processes. Additionally, human activities, including mining and various industrial applications such as animal feed, wood preservation, and pesticide use, can contribute to the release of arsenic into groundwater. Arsenic poses a significant concern in drinking-water supplies due to its toxicity at low levels and its classification as a known carcinogen. In 2001, the United States Environmental Protection Agency (USEPA) lowered the permissible limit of arsenic in public water supplies from 50 µg/l to 10 µg/l, highlighting the importance of monitoring and addressing arsenic contamination in groundwater.

Recently, a myriad of studies conducted in diverse regions of Nigeria has brought attention to an increased susceptibility to arsenic-contaminated groundwater. Despite the absence of published findings on arsenic-polluted groundwater in Monguno, Nigeria this absence does not confer assurance regarding the potability of drinking water, nor does it negate the potential for arsenic contamination. One noteworthy investigation by Orosun (2021) delved into the assessment of arsenic and associated health risks arising from mining activities in select areas of North-central Nigeria. This comprehensive study involved the meticulous collection of 306 samples of soil, water, and guinea corn, subjected to analysis through Atomic Absorption Spectrometry. The discerned outcomes unveiled variable concentrations of arsenic, frequently exceeding permissible consumption limits, thereby substantiating the presence of pollution. Furthermore, the study underscored a pronounced likelihood of non-cancerous health effects attributable to arsenic in drinking water sourced from mining-affected areas.

In another study focusing on arsenic pollution, Ezeabasili et al. (2014) scrutinized the pollution status of surface and subsurface water in Onitsha town, Anambra State, Nigeria. Their investigation disclosed arsenic concentrations in boreholes spanning from 0 mg/L to 1.2507 mg/L. Alarming exceedances of the World Health Organization (WHO) standard of 0.01 mg/L were noted in water sourced from rivers, with a concurrent 87.8% of boreholes proximal to these water bodies surpassing the stipulated WHO threshold. Notably, the study pinpointed sources of arsenic in Onitsha, including refuse dumps, industrial effluents, and sewage. Recognizing arsenic as the most toxic metal on Earth's surface, the study underscored the imperative of stringent monitoring of its production and the necessity for effluent treatment before discharge into the environment.

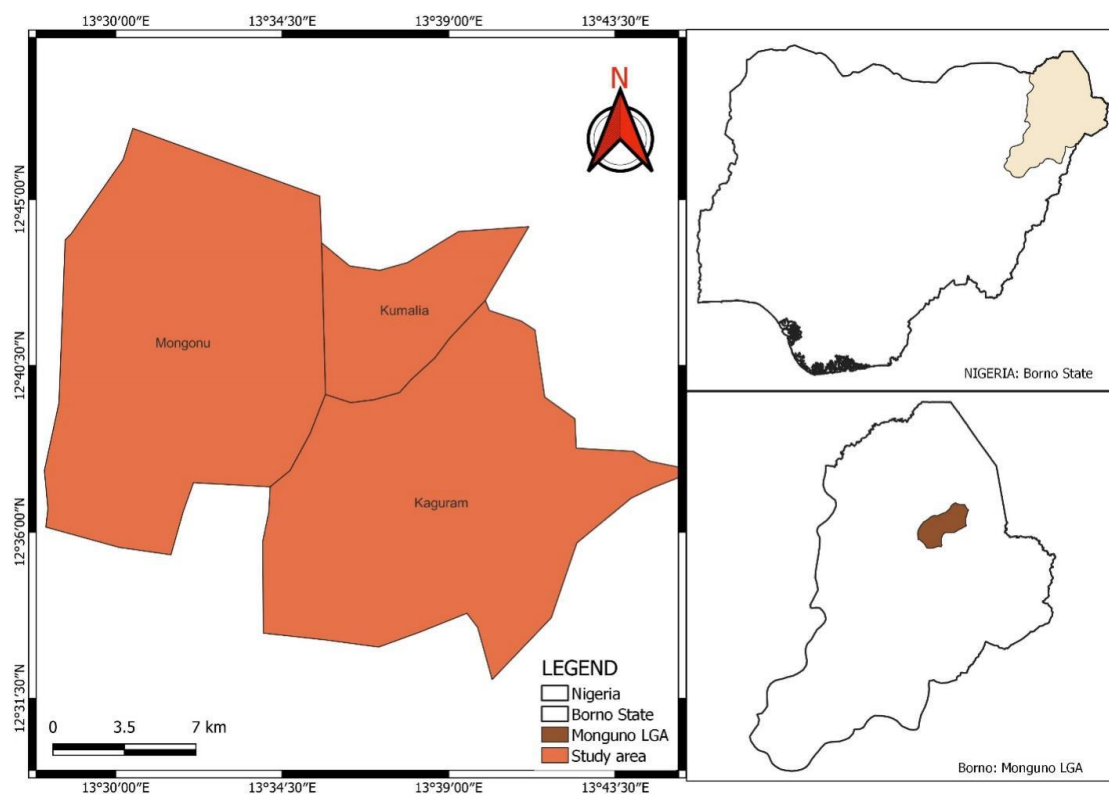
In the Monguno Local Government Area (LGA) of Borno State, ensuring access to high-quality potable water is a significant concern. During the WaSH (Water, Sanitations and Hygiene) cluster meeting on November 8, 2022, it was reported that water quality tests in Monguno town identified elevated arsenic levels in numerous boreholes, prompting the need for further investigation. The presentation underscored the urgency of detailed assessments due to the health implications of arsenic (Meeting discussion, November 8, 2022). Consequently, a thorough examination of boreholes in Monguno and its surroundings for arsenic concentrations is imperative. This assessment will establish a baseline, enabling researchers and policymakers to formulate effective, sustainable solutions for the provision of safe drinking water in the region.

Despite the extensive water sampling efforts conducted by various WaSH partners in Monguno, Nigeria, and the recognized global health risks associated with arsenic-contaminated groundwater, there is a notable absence of comprehensive assessments of arsenic levels and potential sources in different regions of the state, particularly in Monguno. Hence, it is crucial to evaluate the arsenic concentrations in groundwater from various sources in Monguno. This study was therefore undertaken with the aim of determining the arsenic content in the groundwater of all identified boreholes in Monguno, while also assessing the potential health hazards associated with the consumption of this groundwater.

## 2. Materials and Methods

### 2.1 Study Area

The study area, Monguno town, is geographically located at  $12^{\circ}41'0''\text{N}$   $13^{\circ}36'0''\text{E}$  and borders Marte, Mafa, Nganzai, Guzamala, and Kukawa at the fringes of Lake Chad. It covers an area of  $1,913 \text{ km}^2$  and had a population of 109,851 according to the 2006 census. Figure 2 illustrates the study area map, specifically highlighting the discerned water locations within the towns of Monguno, Kumalia, and Kaguram. The hydrology of the Borno Basin comprises atmospheric, surface, and groundwater systems. The region's rainfall intensity is influenced by the climate and other natural factors. Research by Offodile (1993) and Nicolas (2013) indicated that the rainfall intensity gradually decreases from the southern to the northern part of the Chad Basin (Offodile, 1993). Schoeneich (1998) presents a rainfall distribution map of Nigeria, placing the Chad Basin area within the Sahel climatic zone with an isohyet of 600 mm/a. The Chad Formation aquifers typically receive recharge from rainfall through infiltration for the Upper aquifer, whereas the Middle and Lower Zone aquifers mainly recharge within their outcrop areas.



**Figure 2:** Map of the study area in Monguno Local Government Area, Borno State, Nigeria.

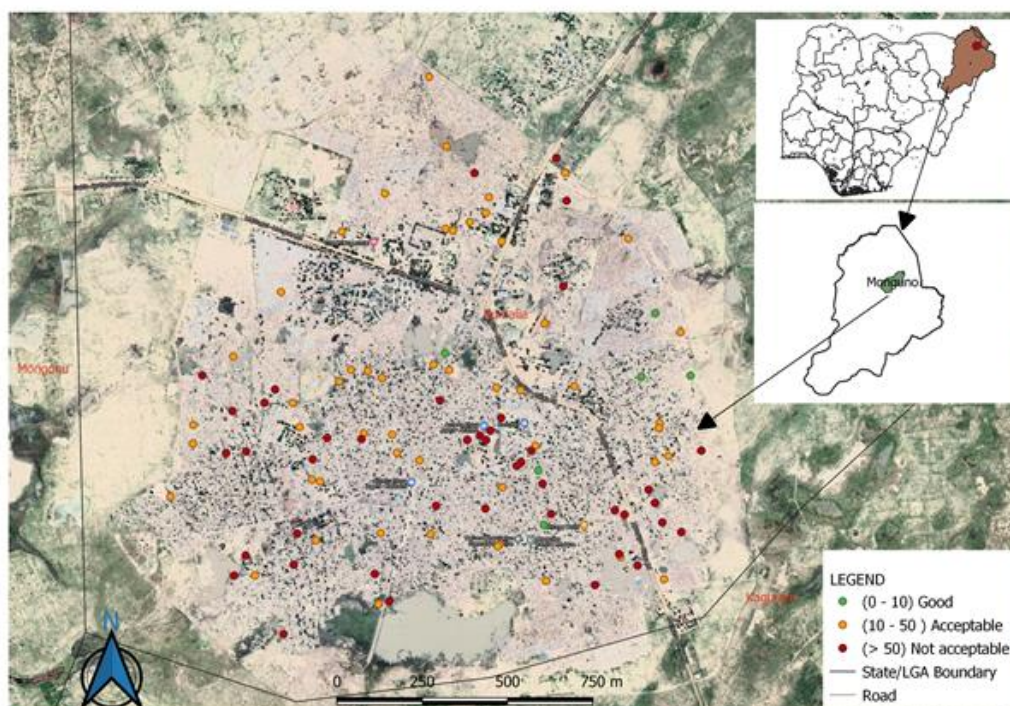
Socio-economically, the majority of the population in Monguno is engaged in fishing, farming, and livestock grazing. However, due to the impact of insurgency in recent years, these activities have been limited. With the improved security situation in Monguno town, farming activities have gradually resumed.

### 2.2 Water Sampling, Preservation and Storage

Groundwater samples used for drinking purposes by the local inhabitants were collected from a total of 102 boreholes across the three zones of the Lake Chad Basin aquifer: Upper, Lower, and Middle Aquifer. The geographical coordinates of the 102 boreholes were acquired through Global Positioning System (GPS) technology. Data accumulated during the research project were subsequently archived within QGIS, a Geographical Information System (GIS), serving as a visual database to facilitate the graphical representation and analysis of information. The data collection process was coordinated in collaboration with WaSH implementing partners responsible for managing the water points in Monguno LGA. The comprehensive sampling

initiative spanned a duration of 13 consecutive days, commencing with the meticulous collection of data and extending through subsequent stages of analysis.

Water samples were collected from every operational borehole identified in Monguno. Prior to the sampling activity, a survey form (on kobo) was administered to gather detailed information about each borehole, including its management, depth, and geographical location (Figure 3).



**Figure 3:** Map of Monguno town showing the concentration of Arsenic in groundwater.

Each of the groundwater samples was collected in two Whirl Pak water sample bags that are well labeled per groundwater sample. The samples were exclusively allocated for arsenic content analysis and were carefully stored post-intake under controlled environmental conditions in a dedicated cooler in Monguno, Nigeria. This storage practice, although not necessitated by microbial concerns, adhered to recommended guidelines to ensure optimal sample preservation for accurate results.

The samples were tested immediately the following day of the sample intake which was driven by the necessity to mitigate any potential alterations in sample integrity over time, thereby safeguarding the precision of the arsenic content analysis results. In addition, unlike microbial tests, the time difference between testing and analysis has no significant impact on the outcome of arsenic tests.

### 2.3 Laboratory Analysis of Arsenic

The laboratory analysis of the groundwater samples was conducted using the Palintest Digital Arsenator Test Kit PT981, Palintest Halma Company, United Kingdom (UK). The Arsenator test kit follows a series of three steps to determine the arsenic concentration in the water samples:

i. Loading the Tri-filter Arsenic Trap (Bung Device):

The Arsenator toolkit, featuring the H<sub>2</sub>S removal filter, red filter paper, and black filter, was meticulously loaded into the Arsenator using forceps. Activation involved inserting the pre-loaded black filter into the Arsenator for 3 seconds.

ii. Sample Preparation:

At this stage, a 50 ml water sample, marked on the container, was poured into a conical flask. A1 reagent and A2 sachet powder were added, and the flask was sealed promptly with a bung.

iii. Arsenic Measurement and Color Comparison:

After 20 minutes, the black paper slide was introduced, displaying arsenic concentration on the digital meter in  $\mu\text{g/L}$ . Results above the digital Arsenator's detection limit ( $100 \mu\text{g/L}$ ) prompted consideration of the dilution factor. Cross-verification was performed using the color comparator, capable of measuring arsenic concentrations up to  $500 \mu\text{g/L}$ .

To ensure precision and accuracy each water sample underwent the specified analysis steps twice, resulting in a total of 204 tested and analyzed samples. The laboratory at the Initiative for Reconstruction and Resettlement (IRR) meticulously adhered to the ISO 17025:2017 guidelines, ensuring compliance with standards for testing laboratory competence, encompassing aspects such as equipment calibration, quality control procedures, and personnel competence. Additionally, strict adherence to the Palintest Arsenator Test Kit Manufacturer's Guidelines was maintained, covering instrument calibration, maintenance, and usage instructions to guarantee the accurate functioning of the test kit. In instances where arsenic concentrations exceeded the digital Arsenator's detection limit, a scientifically derived dilution factor was calculated, following established principles and laboratory protocols. Furthermore, cross-verification was conducted using a color comparator, aligning with recognized colorimetric techniques for arsenic analysis, thereby corroborating results obtained from the digital Arsenator.

## 2.4 Human Health Risk Assessment

In order to evaluate the potential impact of arsenic on human health across the 102 water samples, various parameters including the Average Daily Dose (ADD), Hazard Quotient (HQ), and Cancer Risk Assessment have been computed.

i. Average Daily Dose (ADD):

The estimation of ADD for arsenic through drinking water was conducted utilizing Equation (1):

$$ADD = \frac{C \cdot IR \cdot EF \cdot ED}{AT \cdot BW} \quad (1)$$

In this equation, C denotes the concentration of arsenic in groundwater at averaged for all the 102 water samples in Monguno, IR represents the daily ingestion rate of groundwater, ED specifies the exposure duration, EF indicates exposure frequency, BW is the body weight, and AT signifies the average life expectancy.

ii. Calculation of Hazard Quotient (HQ)

The HQ for arsenic in groundwater at the 102 water points was determined according to the (US-EPA 2005) guidelines using Equation (2):

$$HQ = \frac{ADD}{RfD} \quad (2)$$

Here, RfD represents the oral reference dose for arsenic ( $0.3 \mu\text{g kg}^{-1} \text{ day}^{-1}$ ) (USEPA 2005). An HQ value below 1 is considered indicative of safety.

iii. Cancer Risk (CR) Assessment

The estimation of CR followed the USEPA 2005 guidelines, as expressed in Equation (3):

$$CR = ADD \times CSF \quad (3)$$

Here, CSF denotes the cancer slope factor for arsenic ( $1.5 \text{ mg kg}^{-1} \text{ day}^{-1}$ ). This comprehensive assessment provides valuable insights into the potential health risks associated with arsenic exposure through drinking water in different water sources in Monguno.

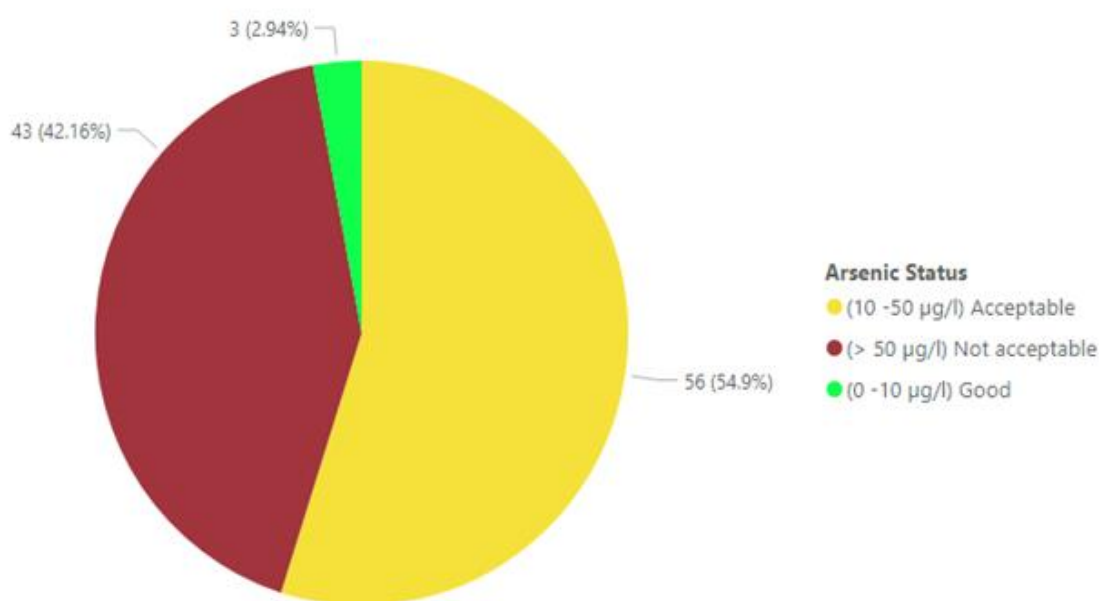
### 3. Results and Discussion

#### 3.1 Arsenic Concentration in water samples

The analysis of the groundwater samples revealed significant variations in the arsenic concentration across the study area. Out of the total 102 samples collected, the results indicate that only 3 samples obtained from shallow wells equipped with hand pumps and deep boreholes, reaching depths of approximately 400 meters, had arsenic concentrations below the permissible limit of safe drinking water, which is set at 10 µg/L by both the World Health Organization (WHO) and the National Standard for Drinking Water Quality (NSDWQ).

Additionally, 56 samples exhibited arsenic concentrations falling within the range of 10 to 50 µg/L. While this concentration level is deemed acceptable with low risk, it is essential to continue monitoring and managing these water sources to prevent potential future increases in arsenic levels. (Table 1, Figure 4)

However, the most concerning finding was that 43 samples showed arsenic concentrations exceeding 50 µg/L (as depicted in Figure 4). These levels surpass the permissible limits for drinking water established by both WHO and NSDWQ. Prolonged exposure to such high levels of arsenic can lead to various health implications and pose significant risks to the local population.



**Figure 4:** Distribution of Arsenic Concentrations in Groundwater Samples

These results underscore the urgent need for intervention and remediation measures to address the presence of elevated arsenic concentrations in the groundwater of the study area. Access to safe drinking water is vital for the well-being of the community, and immediate action is required to mitigate the health risks associated with arsenic contamination.

**Table 1:** Laboratory Results of Arsenic Concentration (µg/L) in Groundwater from 102 Borehole in Monguno

Sample ID number	Arsenic Value -1 <sup>st</sup> Sample (µg/L)	Arsenic Value – 2 <sup>nd</sup> Sample (µg/L)	Average value (µg/L)
Borehole-1	18	18	18
Borehole-2	98	100	99
Borehole-3	28	28	28
Borehole-4	15	17	16

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Borehole-5	28	30	29
Borehole-6	11	11	11
Borehole-7	25	25	25
Borehole-8	24	26	25
Borehole-9	17	19	18
Borehole-10	17	21	19
Borehole-11	25	27	26
Borehole-12	21	19	20
Borehole-13	24	22	23
Borehole-14	22	24	23
Borehole-15	19	21	20
Borehole-16	22	18	20
Borehole-17	17	19	18
Borehole-18	248	252	250
Borehole-19	149	151	150
Borehole-20	22	24	23
Borehole-21	9	11	10
Borehole-22	26	28	27
Borehole-23	31	29	30
Borehole-24	9	11	10
Borehole-25	97	99	98
Borehole-26	360	360	360
Borehole-27	211	209	210
Borehole-28	189	191	190
Borehole-29	15	17	16
Borehole-30	490	490	490
Borehole-31	86	88	87
Borehole-32	151	149	150
Borehole-33	63	61	62
Borehole-34	24	26	25
Borehole-35	20	22	21
Borehole-36	48	46	47
Borehole-37	88	86	87
Borehole-38	121	119	120
Borehole-39	221	219	220
Borehole-40	410	410	410
Borehole-41	11	9	10
Borehole-42	7	9	8
Borehole-43	15	17	16
Borehole-44	34	32	33
Borehole-45	28	30	29
Borehole-46	20	22	21
Borehole-47	41	41	41
Borehole-48	26	28	27
Borehole-49	29	27	28
Borehole-50	89	89	89
Borehole-51	15	17	16
Borehole-52	43	47	45
Borehole-53	17	19	18
Borehole-54	48	50	49
Borehole-55	13	15	14

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Borehole-56	65	65	65
Borehole-57	54	56	55
Borehole-58	21	23	22
Borehole-59	81	83	82
Borehole-60	59	61	60
Borehole-61	150	150	150
Borehole-62	79	83	81
Borehole-63	125	125	125
Borehole-64	135	137	136
Borehole-65	39	41	40
Borehole-66	97	99	98
Borehole-67	44	46	45
Borehole-68	38	40	39
Borehole-69	91	93	92
Borehole-70	93	91	92
Borehole-71	12	16	14
Borehole-72	49	51	50
Borehole-73	13	15	14
Borehole-74	82	84	83
Borehole-75	89	91	90
Borehole-76	67	71	69
Borehole-77	94	92	93
Borehole-78	300	300	300
Borehole-79	22	24	23
Borehole-80	52	48	50
Borehole-81	230	230	230
Borehole-82	81	79	80
Borehole-83	90	90	90
Borehole-84	290	290	290
Borehole-85	13	11	12
Borehole-86	54	56	55
Borehole-87	79	81	80
Borehole-88	9	13	11
Borehole-89	6	4	5
Borehole-90	29	31	30
Borehole-91	37	39	38
Borehole-92	37	37	37
Borehole-93	29	31	30
Borehole-94	22	20	21
Borehole-95	110	110	110
Borehole-96	31	29	30
Borehole-97	68	70	69
Borehole-98	0	0	0
Borehole-99	26	26	26
Borehole-100	97	95	96
Borehole-101	78	80	79
Borehole-102	390	390	390
Average Arsenic concentration			76

The findings from the current investigation reveal that the average arsenic (As) concentration across all water samples was 76 µg/L (refer to Table 1 and Fig. 4). The lowest observed arsenic concentration was 0 µg/L in only one borehole, whereas the highest recorded level of arsenic reached 490 µg/L.

The assessment of arsenic concentrations in groundwater samples from Monguno town reveals a concerning scenario with potential implications for public health and access to safe drinking water. A significant proportion of the sampled groundwater sources (42.2 %) were found to be contaminated with elevated levels of arsenic, exceeding the permissible limits set by WHO and NSDWQ. This indicates a widespread contamination issue within the study area, posing serious health risks to the local population, including skin lesions, respiratory issues, cardiovascular diseases, and an increased risk of cancer. Arsenic exposures may play a role in increasing prostate cancer risk (Yang, 2022).

While a limited number of samples (2.9 %) had arsenic concentrations below the permissible limit, the majority of samples (54.9 %) fell within the acceptable range of 10 to 50 µg/L, with low immediate health risks. However, continuous exposure to even lower levels of arsenic over time can still lead to health issues, emphasizing the need for ongoing monitoring and management.

The geographical distribution of arsenic concentrations, as shown in Figure 2, is dispersed within the study area, suggesting that contamination is not solely based on geography. Nevertheless, boreholes drawing water from the lower aquifer appear to be more susceptible to elevated arsenic concentrations. This observation points to the role of geological factors and aquifer characteristics in arsenic mobilization and its impact on water quality. Haun (2020) on conducted a study on groundwater pollution risk assessment in unsaturated and saturated aquifer and found that the second semi-confined aquifer, or lower aquifer, was predominantly ranked as relatively low (30.29%) and mediate (38.17%) in contamination risk, indicating it is generally less susceptible to pollution compared to the upper aquifer.

### 3.2 Assessment of Human Health Risk

Any detected arsenic concentration exceeding 10 µg/L in water samples holds the potential for adverse human impacts, as emphasized by the World Health Organization (WHO, 2011). Furthermore, a specific human health risk assessment has been meticulously conducted within the framework of this study, aligning with the concerns raised by health and environmental organizations, as well as regulatory authorities at local, regional, and global levels, pertaining to environmental toxicology, food security, and health risks (Shah et al., 2020). The study, as outlined in Table 2, employs calculated risk assessment parameters to investigate the potential transfer of arsenic from water to humans, aiming to predict conceivable health hazards among the local inhabitants of Monguno.

**Table 2:** ADD, HQ and CR values for 102 water sources in Monguno.

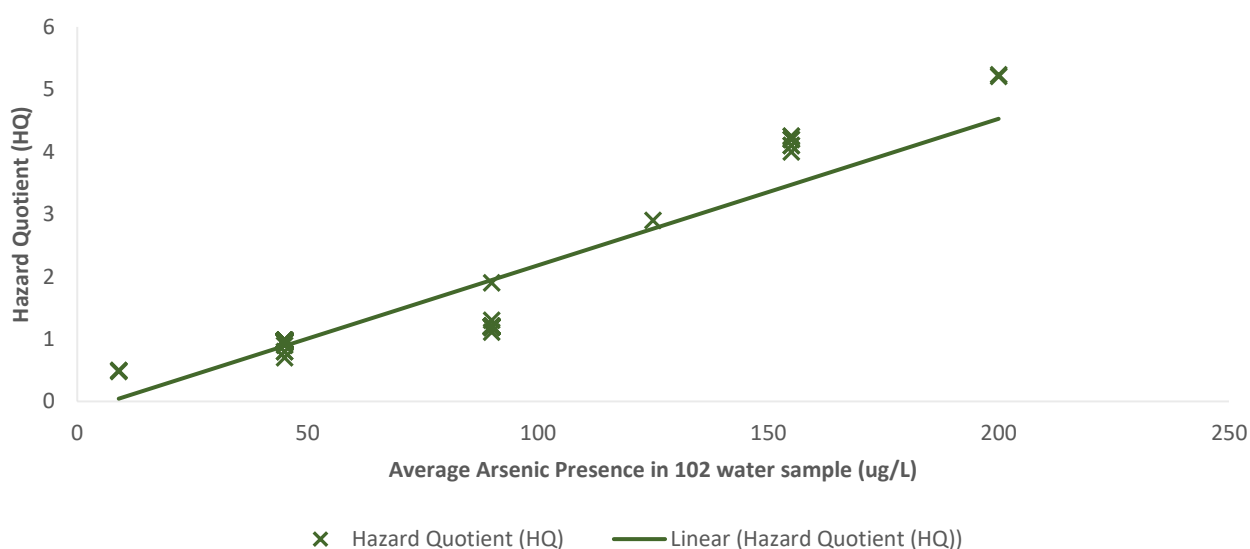
Range of Arsenic concentration (µg/L)	Number of boreholes	ADD (mg/kg/day)	HQ	CR
0-9	3	0.0001487	0.4957	0.000223
10-50	56	0.0002938	0.9793	0.0004407
51-100	25	0.0003614	1.2047	0.0005421
101-200	8	0.001263	4.2101	0.001895
>200	10	0.001576	5.2533	0.002364

The ADD values exhibit a range of 0.0001 to 0.001 mg.kg<sup>-1</sup>day<sup>-1</sup> across 102 water samples in Monguno (refer to Table 4). Notably, the maximum ADD occurs in 10 water samples with arsenic concentrations surpassing 200 µg/L. These samples also exhibit the highest HQ value at 5.2533, signifying an elevated risk corresponding to increased arsenic concentration.

The mean arsenic levels in water samples follow an ascending order concomitant with a rise in arsenic content, irrespective of the varying number of boreholes per arsenic level. Specifically, for 9 µg/L arsenic in 3 boreholes, the mean value is as minimal as 0.000233. In contrast, for arsenic content ranging from 10 to 50 µg/L across 56 boreholes, the mean value escalates to 0.0004407. Meanwhile, samples from the 10 boreholes with the highest arsenic concentrations exhibit a proportional increase in potential CR value, reaching 0.002364. This trend is consistently mirrored in the ADD and HQ values across all 102 sites, as detailed in Table 2.

The elevated values of ADD, HQ, and CR in certain Monguno groundwater samples suggest potential carcinogenic and non-carcinogenic health hazards within the local community. While specific reference values for Monguno are absent, the analogous trend in North Central Nigeria reinforces this observation. Notably, the Hazard Indices (HI) calculated for the well waters consistently exceed the acceptable range of 1.00E-6 to 1.00E-4, indicating heightened health hazards and cancer risks (Orosun, 2021).

### Hazard Quotient per Arsenic presence in Water Sample



**Figure 5:** Model for representing the hazard quotient for concentration of arsenic in Monguno

A linear model depicting the hazard quotient per arsenic sample for all 102 samples is presented in figure 5. The graph reveals a clear linear relationship, allowing for the extrapolation of known arsenic levels within the Monguno geographical location. The congruent findings in this study align with the observations made by Etim (2017), who identified a linear relationship in hazard indices, ADD, HQ, and HI across 210 groundwater samples collected from 35 shallow wells.

The assessment of arsenic concentrations in groundwater samples from Monguno town reveals a concerning scenario with potential implications for public health and access to safe drinking water. A significant proportion of the sampled groundwater sources (42.2 %) were found to be contaminated with elevated levels of arsenic, exceeding the permissible limits set by WHO and NSDWQ. This indicates a widespread contamination issue within the study area, posing serious health risks to the local population, including skin lesions, respiratory issues, cardiovascular diseases, and an increased risk of cancer. Arsenic exposures may play a role in increasing prostate cancer risk (Yang, 2022).

#### **4. Conclusion and Recommendations**

The results of this research highlight a critical water quality issue in Monguno town, Borno State, Nigeria, with a significant number of groundwater samples showing elevated arsenic concentrations, posing potential health risks to the local population. Urgent measures are needed to address this pressing concern and ensure access to safe drinking water for the community. Out of the 102 groundwater samples collected, 43 samples exhibited arsenic concentrations above the permissible limits set by both the World Health Organization (WHO) and the National Standard for Drinking Water Quality (NSDWQ). Prolonged exposure to arsenic-contaminated water can lead to serious health implications, making it imperative to take immediate action to safeguard public health. While some samples (3 out of 102) fell within safe limits, and others (56 out of 102) were within an acceptable range with low risk, continued monitoring and effective management of these sources are essential to prevent potential future increases in arsenic levels.

Collaboration between government agencies, non-governmental organizations, research institutions, and the local community is vital to formulate and implement comprehensive remediation plans. Additionally, continued research and monitoring efforts are necessary to better understand the sources and distribution of arsenic in groundwater and to assess the long-term effectiveness of remediation measures.

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